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SAFETY OF FUEL PUMP CIRCUITS IN FUEL TANKS OF ROAD VEHICLES USING UNLEADED GASOLINE OR METHANOL

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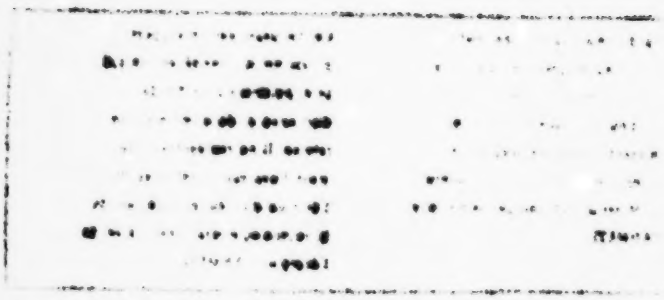

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Safety of Fuel Pump Circuits in Fuel tanks of Road Vehicles Using Unleaded Gasoline or Methanol

by

E.E. Dainty[1] and G. Lobay[2]

ABSTRACT

In previous work various road vehicle alternative fuels were tested in conjunction with electrical devices normally used in fuel tanks, such as submersible fuel pumps and level sensors. The tests simulated the operation of these devices both under normal and fault electrical conditions at various temperatures. The intent was to determine whether or not sparks from them could ignite the vapours above the fuel in the tank, thereby causing an explosion. These tests were performed using saturated vapour-air mixtures.

This report supplements the previous information obtained. Two additional fuels, unleaded gasoline and methanol, were tested in a range of temperatures, using a fuel pump circuit and IEC breakflash apparatus for ignition.

The results showed that the high current levels associated with the fuel pump test circuit somewhat extended, in a consistent way, the upper and lower ranges of flammability for the respective vapours, relative to the lower levels of test current used previously.

KEYWORDS: Methanol fuels, fuel tanks, road vehicles, intrinsic safety, explosions.

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INTRODUCTION

This report is the result of a request received by the Canadian Explosive Atmospheres Laboratory (CEAL) from Transport Canada to further investigate the properties of 100% methanol fuel, and unleaded gasoline. This work was to supplement the work already done and reported in Mining Research Laboratories Divisional Reports MRL 88-33 (TR) [1] and MRL 89-66(TR) [2].

In the previous work mentioned above [1, 2], five fuels were assessed, these being:

methanol;
methanol with cetane improver;
winter grade gasoline:
85% methane and 15% gasoline;
85% methane, 13% gasoline and 2% butane.

The previous work had three main objectives:

- to plot a curve for each fuel showing the relationship between ignition current and ambient temperature for a saturated fuel-air mixture;

- to show that there was ample capacity in a fuel pump circuit to ignite a saturated fuel-air mixture within the ignitible range of the vapour;

- to show what would occur to the limits of flammability for a fuel when the vapour-air mixture was no longer in the saturated state.

This report adds more information relative to the first two objectives.

The results of the first objective consisted of a family of curves shown as Figure 2. With reference to the other two

objectives, it was shown that there is ample capacity in a fuel pump circuit to ignite vapour-air mixtures within their flammable ranges, and it was also shown that as a vapour-air concentration is reduced from the saturated state, there is a corresponding broadening of the flammable range of that mixture.

The apparatus used to assess these fuels consisted of the standard IEC breakflash apparatus [3] which is designed to interrupt a circuit and produce sparks in the presence of an explosive atmosphere. The IEC apparatus was connected to a standard calibration circuit which was used to determine the smallest possible electrical current, for a given fuel and temperature, at which the generated sparks could ignite the surrounding explosive mixture. The standard calibration circuit consisted of a series-connected 24 Vdc regulated power supply, a 95 mH air core inductor, and a resistance decade box for setting the test current.

The objective of this report was to determine the limits of flammability of vapour-air mixtures for unleaded gasoline, methanol and diesel fuels, using a fuel pump test circuit in conjunction with the IEC breakflash apparatus. The previous work concentrated on obtaining results in the lower spectrum of ignition currents; this work concerned itself with a much higher spectrum of ignition currents (about 50-100 times higher).

METHOD

The method used was essentially the same as that used to generate the family of curves described in Fig. 2, but with some differences in the IEC test apparatus.

Tungsten electrodes and a cadmium disk are normally used in the IEC apparatus, which have been shown to produce the best results where test currents are less than a few amps. This arrangement is not suitable for higher test currents because the tungsten

electrodes overheat, often becoming red hot, resulting in loss of the physical characteristics needed for good contact separation, and severe loss of breakflash apparatus sensitivity.

After some experimentation, reasonably reliable results, as determined by the calibration circuit, were obtained using 20 AWG copper wire with a steel disk. It was found that the contact pressure of the copper wire against the steel disk was an important factor in determining the sensitivity of the apparatus. Maximum sensitivity was obtained by adjusting the electrodes so that they would extend 1 mm below the surface of the disk after travelling across its surface. A small coil (formed by winding two turns of the electrode wire around a 2 mm mandrel) was formed into each electrode to improve its spring characteristics. Fig. 1 shows the electrode arrangement.

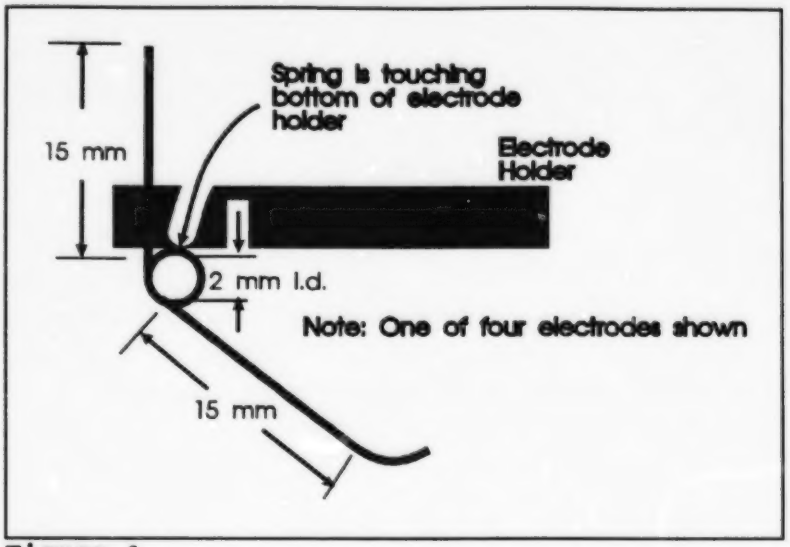

Figure 1
Copper Electrode

The calibration circuit consisted of a series connected 95 milliHenry air core inductor, 24 Vdc power supply, and resistance to limit the current to specified values. An 8.3% methane-air test gas mixture was used to calibrate the apparatus. Each day prior to and after a test series using the fuel pump, the breakflash apparatus was operated in this calibration circuit at 180 mA. The apparatus was deemed to have been working correctly

if ignition was obtained after five minutes of operation, roughly equivalent to 1280 circuit interruptions.

The test circuit consisted of a 2.2 Chrysler turbo fuel pump in a 12 Vdc (nominal) circuit, connected directly to the breakflash apparatus with no current limiting resistance. The pump was immersed in water for the tests to simulate its working under load, which would be the normal operating condition. At times the voltage was somewhat higher (about 13.5 Vdc) because the electrical source was an automotive battery. This slight variation in voltage had no appreciable effect on the results obtained. The fuel pump circuit produced large sparks in the IEC apparatus, as it drew approximately 11 amps whilst pumping water.

After calibration, the breakflash apparatus was operated in a saturated vapour-air mixture at the temperature of interest for five minutes while connected to the fuel pump circuit, and observed for ignitions.

RESULTS

Tables 1 and 2 show whether or not ignition was obtained, using the fuel pump test circuit already described. Each test represents five minutes' operation of the breakflash apparatus at the indicated temperature, with sparking occurring in a saturated vapour-air test mixture.

Test No.	Methanol Temperature (°C)	Ignition?
1	8	no
2	10	no
3	12	no
4	14	yes
5	13	yes
6	12	yes
7	10	no
8	12	yes
9	10	yes
10	8	yes
11	8	no
12	6	no
13	6	no
14	30	yes
15	34	no
16	32	no
17	32	no
18	32	no
19	30	yes

Table 1 - Methanol Tests

Test No.	Unleaded Gasoline Temperature (°C)	Ignition?
1	-42	no
2	-40	yes
3	-42	yes
4	-34	yes
5	-30	yes
6	-26	yes
7	-24	yes (weak flame)
8	-22	no
9	-44	no
10	-42	yes
11	-44	yes
12	-46	no
13	-46	yes
14	-48	no
15	-48	no
16	-48	no
17	-22	no
18	-22	no
19	-22	no

Table 2 - Tests With Unleaded Gasoline

The data was incorporated into the curves shown in Figure 2, which also includes the ignition information obtained in the

previous work. Note that the vertical scale is proportioned differently in the high current region.

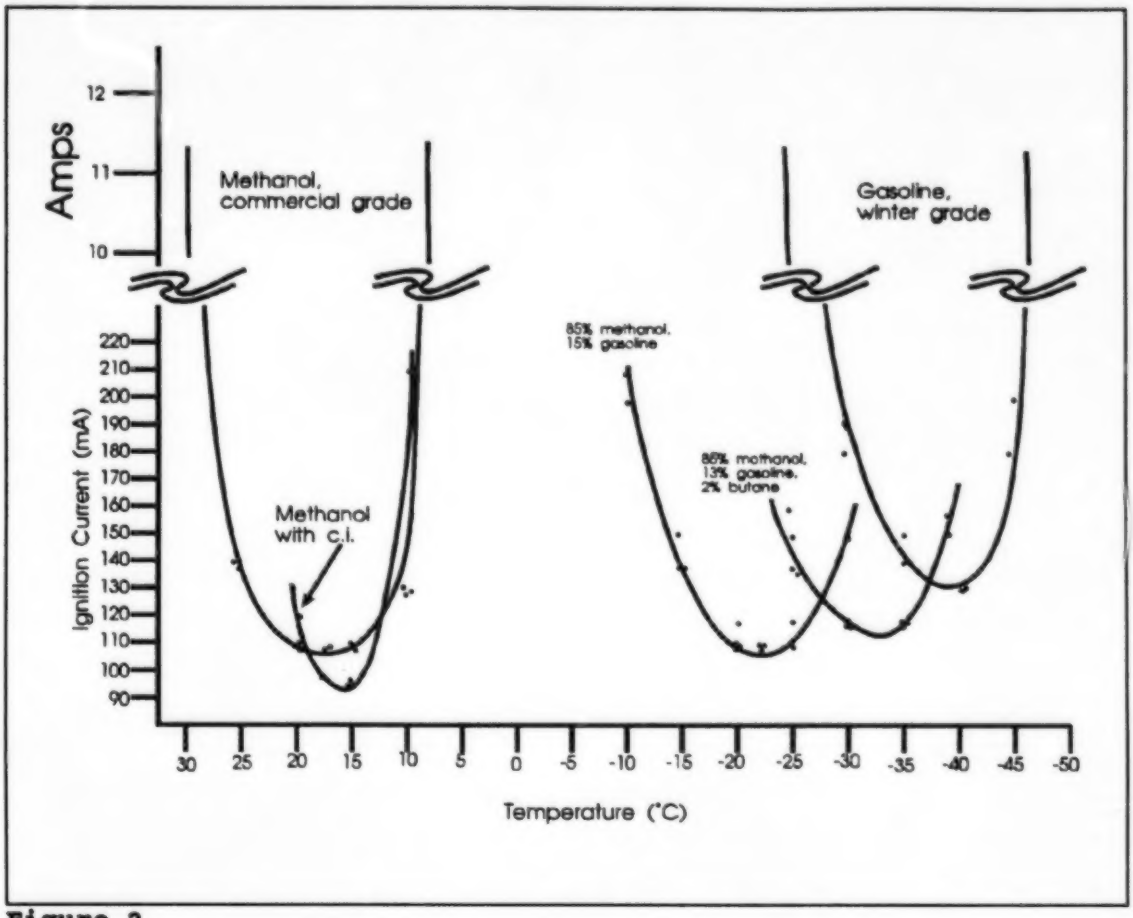

Figure 2
Ignition Characteristics of Fuels, Including High Current Data

DISCUSSION OF RESULTS

The high test current effectively determined the asymptotes on the left (rich mixture) side and right side (lean mixture) for each curve. As the temperature was gradually changed, it became increasingly difficult to observe whether or not an ignition had occurred, due to the relative weakness of the explosion. At the

low temperatures, many equipment breakdowns occurred since it was never designed to operate in this temperature range. The data shown in Tables 1 and 2, when plotted, corresponds with asymptotic projections for the subject curves.

In general, as more and more ignition energy is liberated into an explosive mixture, ignitions of the fuel-air mixture can be obtained within a wider and wider temperature range. If flames, rather than sparks, (such as the flames produced from a pyrotechnic device), could be used as the ignition source, this yet greater ignition energy would be able to initiate combustion of mixtures not generally ignitible with the level of sparking produced by the IEC apparatus.

No data was obtained with diesel fuel. To produce a saturated vapour concentration using diesel fuel, the temperature of the breakflash apparatus would have to be elevated to a point outside its operating limits. The breakflash apparatus has many components constructed from plastics which would have begun to seriously degrade at the required operating temperature.

CONCLUSIONS

The data shows good correspondence with the previously obtained data. In inductive fuel pump circuits, at approximately 10 Amps, the explosive range of methanol was shown to be from 8°C to 30°C. In the case of unleaded gasoline under the same test conditions, the explosive limits were found to be in the range -24°C to -46°C.

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